

**EXAMINER'S AMENDMENT**

An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

Authorization for this examiner's amendment was given in a telephone interview with Michael Krawzsenek on 11/4/10.

The application has been amended as follows:

1. (currently amended) An image segmentation method for estimating boundaries of layers in a multi-layer body, said method comprising:  
providing image data of the multi-layer body using IVUS image data, the image data representing a plurality of image elements;  
determining a plurality of initial interfaces corresponding to regions of the image data to segment; and  
concurrently propagating the initial interfaces corresponding to the regions to segment and thereby estimating the boundaries of the layers of the multi-layer body, propagating the initial interfaces comprising using a fast marching model based on a probability function describing at least one characteristic of the image elements,  
wherein the multi-layer body is a multi-layer blood vessel.

2. (original) An image segmentation method as defined in claim 1, wherein:
  - determining each initial interface comprises defining the initial interface as a zero level of a given function; and
  - propagating each initial interface comprises moving the given function according to a speed function.
3. (cancelled)
4. (original) An image segmentation method as defined in claim 1, wherein the image elements comprise pixels and wherein the fast marching model is based on a probability density function estimating a color map of the pixels for each region of the image data.
5. (original) An image segmentation method as defined in claim 1, wherein the image elements comprise pixels and wherein the fast marching model is based on a gradient function estimating a color map of the pixels for each region of the image data.
6. (currently amended) An image segmentation method as recited in claim [[3]] 1, wherein determining each initial interface comprises:

manually tracing an initialization contour in a longitudinal plane of the IVUS image data;

transposing reference points of the initialization contour to intersecting IVUS 2D frames of the IVUS image data; and

- defining the initial interface from the transposed reference points in the IVUS 2D frames.
7. (original) An image segmentation method as defined in claim 6, wherein defining the initial interface comprises tracing shrunk contours from an interface passing by the reference points.
  8. (original) An image segmentation method as recited in claim 6, wherein manually tracing an initialization contour comprises tracing a plurality of initialization contours.
  9. (currently amended) An image segmentation method as recited in claim [[6]] 8, wherein transposing reference points of the initialization contour comprises transposing reference points from the plurality of initialization contours.
  10. (original) An image segmentation method as recited in claim [[3]] 1, wherein:
    - the image elements comprise pixels each having a color map; and
      - using a fast marching method comprises estimating a color map of pixels in each of the regions to segment in the IVUS 2D frames of the IVUS image data using a mixture of probability density functions.
  11. (original) An image segmentation method as defined in claim 10, wherein the probability density functions comprise Rayleigh probability density functions.

12. (original) An image segmentation method as defined in claim 10, wherein the probability density functions comprise Gaussian probability density functions.
13. (original) An image segmentation method as recited in claim 10, wherein using a mixture of probability density functions comprises determining an occurring probability value of the gray levels of the pixels.
14. (currently amended) An image segmentation method as recited in claim 10, wherein using a mixture of gray level probability density functions comprises iteratively finding mixture parameters via an Expectation Maximization (EM) algorithm, comprising:
  - a) calculating a cost function given an observed value of said color map and a previous estimate of said mixture parameters;
  - b) maximizing said cost function to analytically evaluate a new estimate of said mixture parameters;
  - c) initializing said previous estimate of said mixture parameters to said new estimate of said mixture parameter if both are different; and
  - d) repeating a) to c) until said previous estimate of said mixture parameters is the same as said new estimate of said mixture parameters.
15. (currently amended) An image segmentation method as recited in claim 1, wherein propagating the initial interfaces comprises constructing an arrival time function algorithm, comprising:

- a) defining a speed function for the initial interfaces in terms of said probability function;
  - b) propagating the interface by selecting an interface point having a smallest arrival time;
  - c) calculating the arrival time and speed function of neighbors of the interface point; and
  - d) repeating a) to c) until the propagating initial interfaces have all propagated across the regions to segment.
16. (original) An image segmentation method as recited in claim 15, wherein repeating a) to c) is performed until the propagating initial interfaces are stationary.
17. (original) An image segmentation method as recited in claim 15, wherein said neighbors comprises a number of pixels located around the interface point having the smallest arrival time.
18. (original) An image segmentation method as recited in claim [[3]] 1, wherein providing IVUS image data comprises pulling back in the multi-layer blood vessel a catheter equipped with an IVUS image data acquisition tool.
19. (original) An image segmentation method as recited in claim [[3]] 1, wherein providing IVUS image data comprises:
- a) acquiring IVUS data;

- b) digitizing image data from the IVUS data on a pixel matrix;
  - c) storing the pixel matrix in 2D IVUS frames; and
  - d) calculating an estimation of mixture parameters of a probability density function forming said probability function.
20. (currently amended) An image segmentation method as recited in claim [[3]] 1, wherein providing IVUS image data comprises:
- a) acquiring in-vivo 2D IVUS frames;
  - b) generating segmented contours by tracing initialization contours on longitudinal planes of said IVUS image data and transposing reference points of said initialization contours on said segmented contours; and
  - c) applying an image-formation model to said segmented contours generating simulated 2D IVUS frames.
21. (original) An image segmentation method as recited in claim 20, wherein applying an image formation model comprises:
- a) applying an acoustic impedance variations function to the segmented contours;
  - b) expressing said acoustic impedance variations function in polar coordinates;

- c) processing said acoustic impedance variations function in polar coordinates with a polar spread function via a 2D convolution operator generating a polar radio-frequency image;
  - d) expressing said radio-frequency image in polar B-mode image; and
  - e) generating said simulated 2D IVUS frames by expressing said polar B-mode image in Cartesian coordinates.
22. (currently amended) An image segmentation method for estimating boundaries of layers in a multi-layer body, said method comprising:
- a) providing image data of the multi-layer body using IVUS image data, the image data representing a plurality of image elements;
  - b) determining a plurality of initial interfaces corresponding to regions of the image data to segment; and
  - c) concurrently propagating the initial interfaces corresponding to the regions to segment said regions and estimate the boundaries of the layers of the multi-layer body, propagating the initial interfaces comprising using a fast marching model based on a gradient function describing at least one characteristic of the image elements,  
wherein the multi-layer body is a multi-layer blood vessel.
23. (original) An image segmentation method as defined in claim 22, wherein the image elements comprises pixels having a gray level, and wherein the fast

marching model is based on a gray level gradient function of the pixels for each region of the image data.

24. (original) An image segmentation method as recited in claim [[3]] 1, wherein providing IVUS image data comprises undersampling an initial resolution of said IVUS image data in  $l$  resolution levels of IVUS 2D frames, each resolution levels being a  $2^l$  fraction of said initial resolution of said IVUS image data.
25. (original) An image segmentation method as recited in claim 24, wherein propagating the initial interfaces according to a fast-marching model comprises:
  - a) estimating probability functions in the IVUS image data for obtaining image segmentation results of a first lowest resolution level amongst remaining  $l$  resolution levels;
  - b) mapping the segmentation results into a second lowest resolution level amongst remaining  $l$  resolution levels; and
  - c) repeating a) and repeating b) until the first lowest resolution level is said initial resolution level of said IVUS image data.
26. (original) An image segmentation method as recited in claim [[3]] 1, wherein providing IVUS image data comprises generating  $l$  scale levels of IVUS 2D frames from an initial scale of said IVUS image data, each scale level being a function of a  $2^l \times 2^l$  portion of said initial scale of said IVUS image data.

27. (currently amended) An image segmentation method as recited in claim [[35]] 26, wherein propagating the initial interfaces according to a fast-marching model comprises:
- estimating probability functions in the IVUS image data for obtaining image segmentation results of a first highest scale level amongst remaining / scale levels;
  - mapping the segmentation results into a second highest scale level amongst remaining / scale levels; and
  - repeating a) and repeating b) until the first highest scale level is said initial scale level of said IVUS image data.
28. (currently amended) An image segmentation method as recited in claim [[3]] 1, wherein determining a plurality of initial interfaces comprises:
- selecting a subset of contiguous 2D IVUS frames from said IVUS image data;
  - generating initial interfaces of an inner-layer region estimating an inner layer of the multi-layer blood vessel;
  - searching an initial interface of a side layer of the vessel from said inner-layer region;
  - calculating a likelihood map for said side layer and growing a side-layer region from said map; and

- e) fitting said inner-layer region and said side-layer region on each contiguous 2D IVUS frames of said subset.
29. (original) An image segmentation method as recited in claim 1, wherein using a mixture of gray level probability density functions comprises iteratively finding mixture parameters via a parameter estimation algorithm comprising:
- a) simulating realizations of a hidden data information according to a posterior distribution;
  - b) calculating an estimate of said mixture parameters with a parameter estimator;
  - c) repeating a) and b) until convergence of said mixture parameters.

Claims 30-33(cancelled)

34. (original) An image segmentation method as defined in claim 1, wherein the image data comprises B-mode IVUS image.
35. (original) An image segmentation method as defined in claim 1, wherein the image data comprises RF IVUS image.
36. (original) An image segmentation method as defined in claim 1, wherein the fast marching model is based on a probability function estimating the gray level distribution of pixels of the image data.

The following is an examiner's statement of reasons for allowance: Limitations pertaining to "providing image data of the multi-layer body using IVUS image data;

Art Unit: 2624

concurrently propagating the initial interfaces corresponding to the regions to segment and thereby estimating the boundaries of the layers of the multi-layer body, propagating the initial interfaces comprising using a fast marching model based on a probability function describing at least one characteristic of the image elements, wherein the multi-layer body is a multi-layer blood vessel", in conjunction with other limitations present in the independent claims, distinguish over the prior art.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Any inquiry concerning this communication or earlier communications from the examiner should be directed to ATIBA O. FITZPATRICK whose telephone number is (571)270-5255. The examiner can normally be reached on Monday - Friday.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Samir A. Ahmed can be reached on (571)272-7413. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/A. O. F./  
Examiner, Art Unit 2624

/Samir A. Ahmed/  
Supervisory Patent Examiner, Art Unit 2624